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INSTITUTE FOR DEFENSE ANALYSES

# Technology Transition: Lessons from the DARPA MEMS Program

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# PREFACE

This document was prepared for the Defense Advanced Research Projects Agency, Microsystems Technology Office, under a task entitled Microelectromechanical Systems Development and Insertion.

# Technology Transition: Lessons from the DARPA MEMS Program

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Science and Technology Division, Institute for Defense Analyses, Alexandria, Virginia
for Presentation to the Technology Transfer Society Annual Meeting
July 20–22, 2000, Austin, Texas

# Presentation Overview

IDA

- Objective
- Definitions
- MEMS Technology at DARPA
- Institute for Defense Analyses
- Transition Barriers
- Lessons Learned

# Objective

- Identify lessons learned in transitioning MEMS technology from the laboratory to the field
- Share lessons from technology transition experience relevant to technology transfer processes

# Presentation Overview

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# Terms of Reference (1)

IDA

- Technology Transfer and Technology Transition share common goal
  - more uses of R&D products
- Transition
  - Focus on moving from Laboratory to Field within domain of initial concern (needs, requirements)
- Transfer
  - Focus on taking existing intellectual property and expanding applications, use, and number of product sources across multiple domains

# Terms of Reference (2)

- Common Processes
  - Matching user (consumer) requirements and needs to product (producer) capabilities
  - Identifying Barriers
  - Developing Strategies to Overcome Those Barriers
  - Making Transition/Transfer Worthwhile

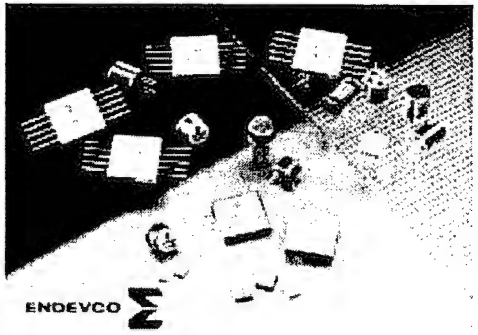
# Charting Transition Progress


- Products Incorporated in Fielded Military Systems
- Products Included in Program Objective Memorandum (POM) for Future New Systems
- Products Included in POM for Preplanned Product Improvement
- Products Included in Service Advanced Technology Demonstrations (ATD) or OSD/Joint Service Advanced Technology Concept Demonstrations (ACTDs)
- Products Covered by New Industry/Government Standards
- Product RDT&E and Doctrine Development Efforts Incorporated as Part of Military Service/DOD Component Activities

# Commercial Packaged MEMS

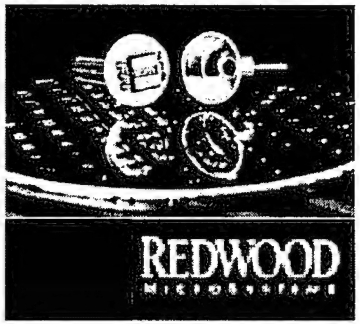
IDA

Microsensors

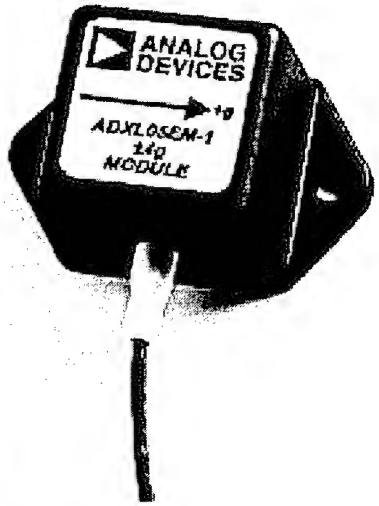




Print Cartridges




Microvalves



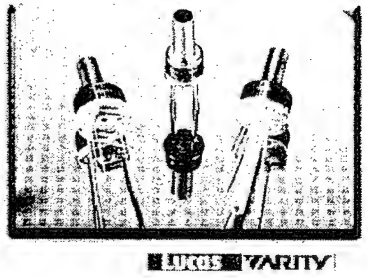

Accelerometers


Microfluidics

| Estimated MEMS Sales | |
|---|---|
| 1997: | $1.2 billion |
| 1998: | $1.3 billion |
| 1999: | $1.5 billion |
| 2000: | $1.8 billion |

Source:
Frost and Sullivan (1997)


Projectors




Pressure Sensors

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# Defense Advanced Research Projects Agency

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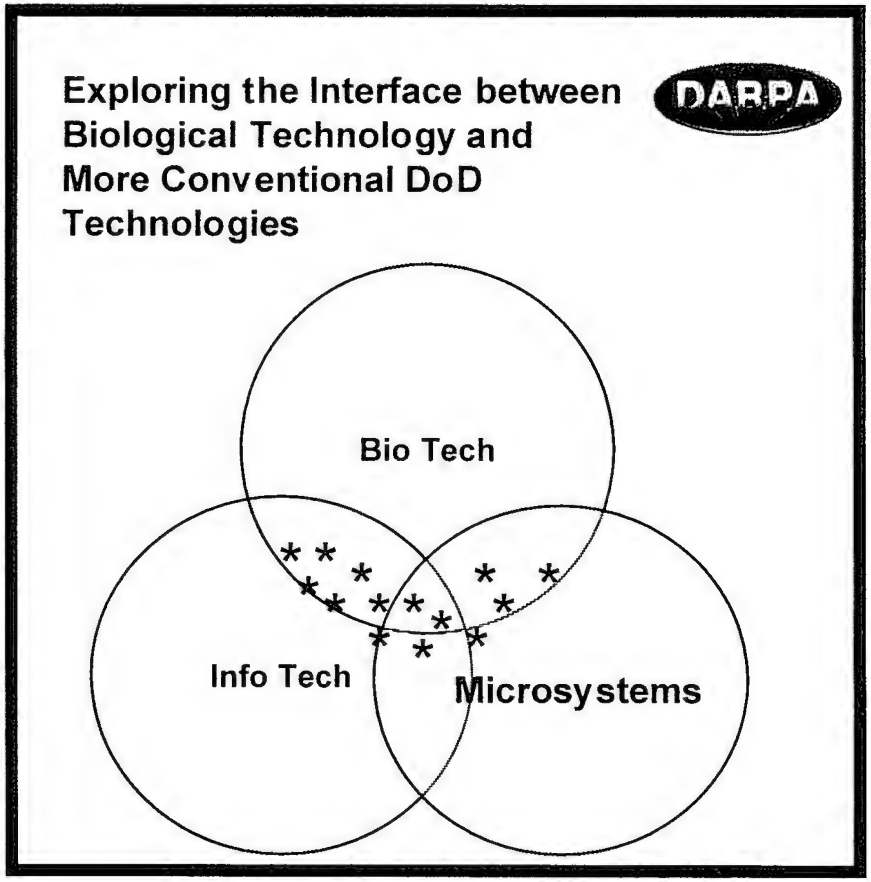
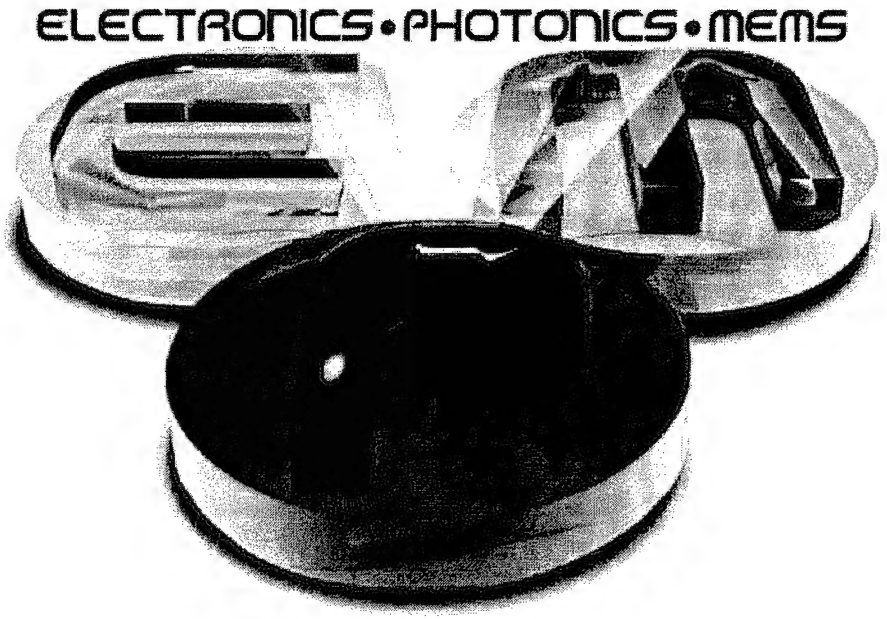
- Develop imaginative, innovative and high-risk research ideas going well beyond the normal evolutionary developmental approaches
- Pursue these ideas from the demonstration of technical feasibility through the development of prototype systems



# DARPA's Microsystems Technology Office

IDA

- Focus on the heterogeneous microchip-scale integration of electronics, photonics, and microelectromechanical systems (MEMS).
- High-risk/high-payoff technology seeks
  - **solutions to problems of protection from biological, chemical and information attack**
  - **technology to provide operational dominance for mobile distributed command and control, combined manned/unmanned warfare**
  - **Infrastructure and methods for dynamic, adaptive military planning and execution**



# DARPA MEMS Program (1)

From November 1992 Cover of Scientific American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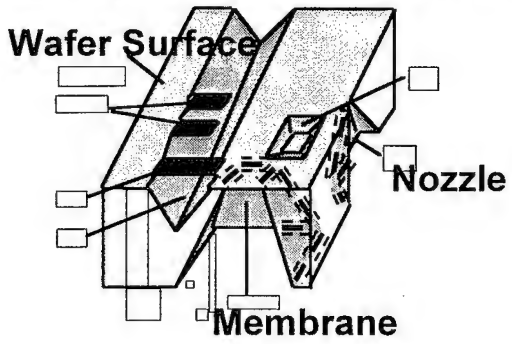
- The long-term goals of DARPA:
  - merge information processing with sensing and actuation to realize new systems and strategies
  - bring co-located perception and control to the physical, biological, and chemical environment.
- Short-term goals include the following:
  - demonstration of key devices, processes and prototype systems using MEMS technologies
  - development and insertion of MEMS products into commercial and defense systems
  - lowering the barriers to access and commercialization by catalyzing an infrastructure that can support shared, multi-user design, fabrication and testing

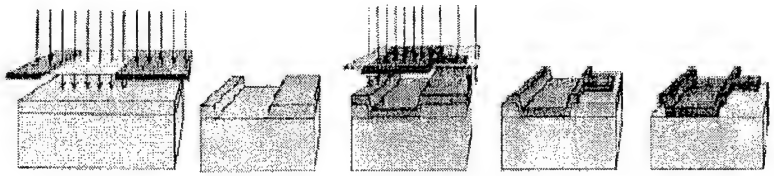
# DARPA MEMS Program (2)

IDA

## Bulk Micromachining

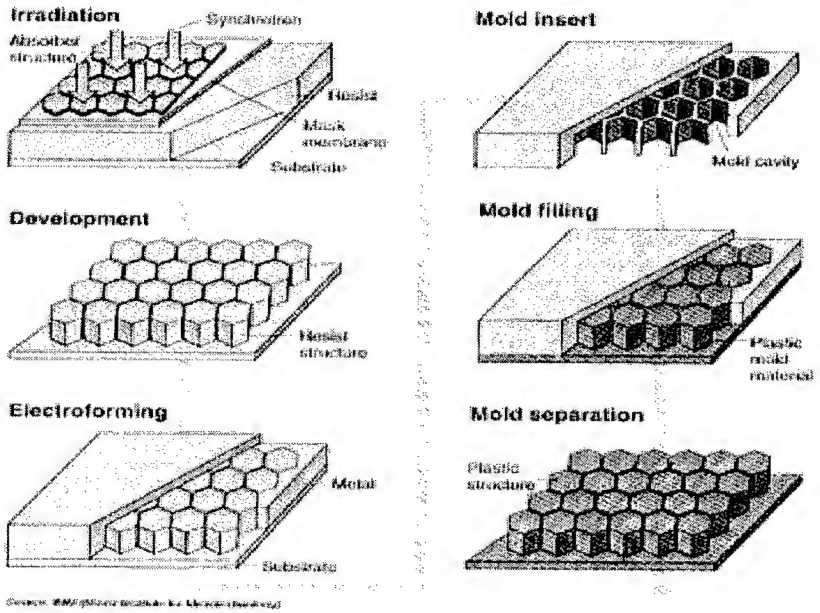



## Surface Micromachining



- Built on microelectronics manufacturing technology

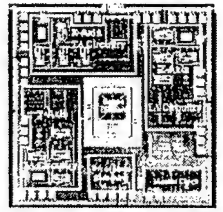
**LIGA*, Deep UV**

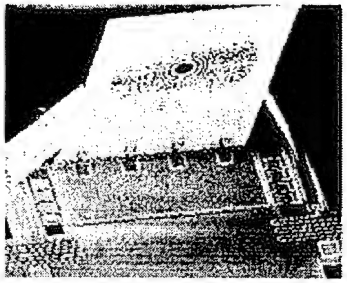



Source: IMM (Mainz Institute for Microtechnology)

# Military Applications of MEMS

- inertial navigation units on a chip—munitions guidance and personal navigation
- distributed unattended sensors—border control, environmental monitoring, security surveillance, and process control
- integrated fluidic systems—miniature analytical instruments, hydraulic and pneumatic systems, propellant and combustion control
- weapons safing, arming and fuzing—improved current warhead systems and enhanced safety and reliability
- embedded sensors and actuators—condition-based maintenance; on-demand amplified structural strength in lower weight weapons systems/platforms and disaster-resistant buildings
- mass data storage devices—densities of terabytes per square centimeter
- integrated micro-optomechanical components—combat identification, data displays, and fiber-optic switches/modulators
- active, conformable surfaces—distributed aerodynamic aircraft control, adaptive optics, and precision parts and material handling





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# Institute for Defense Analyses

IDA

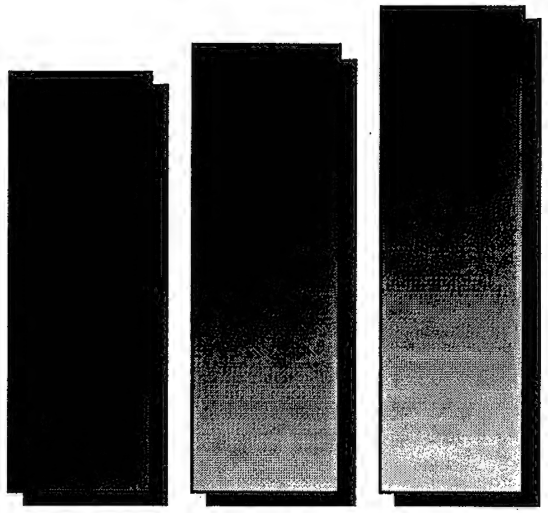
- IDA's Charter
  - Assist the Office of the Secretary of Defense, the Joint Staff, the United Commands, and Defense Agencies in addressing important national security issues...requiring scientific and technical expertise
- IDA's Corporate Structure
  - 501 (C)(3) Nonprofit Research and Development Corporation, incorporated in the District of Columbia
  - Independent Board of Trustees
- IDA's Role as an FFRDC
  - Neutral competence, technical referee among services, contractors
  - Prohibited from competing with the private sector

See www.ida.org for additional information about IDA

- Six Divisions with Core Competencies
  - Systems Evaluations
  - Technology Assessments
  - Resource and Support Analyses
  - Force and Strategy Assessments
  - High-Performance Computing and Communications

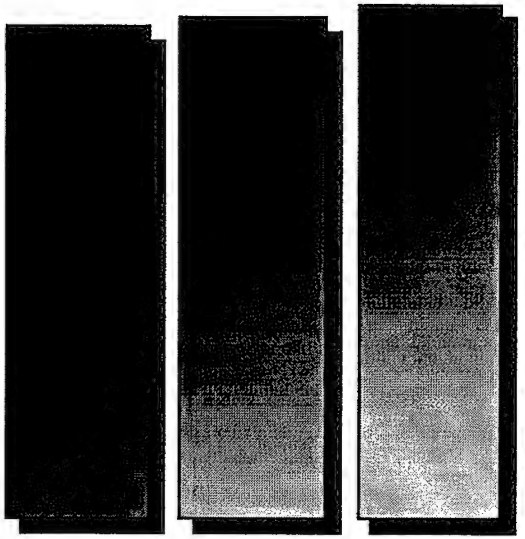
# IDA at a Glance

IDA Revenue, 1997–1999
(in $ Millions)



$103.0M '97 $110.5M '98 $120.3M '99

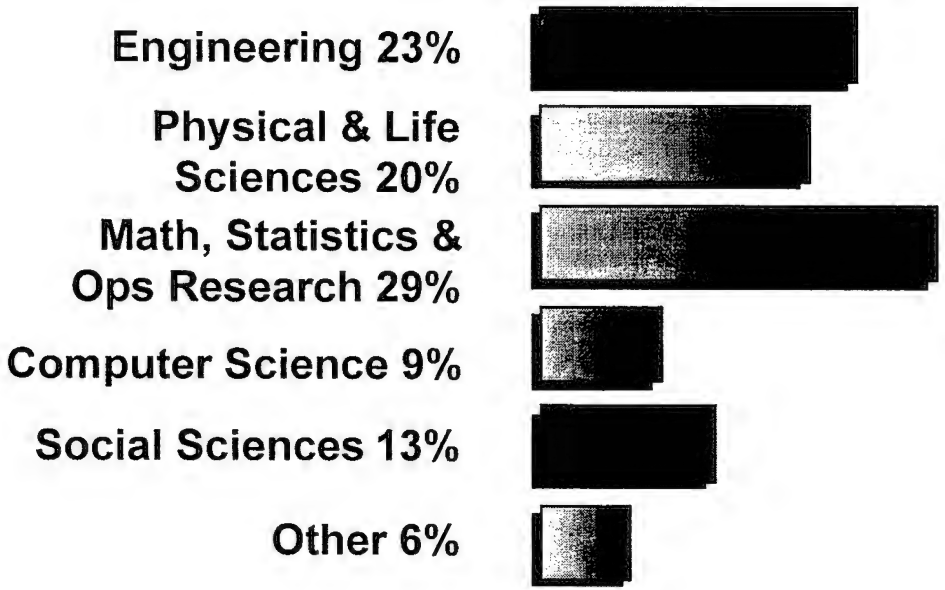
Total Employees, 1997–1999



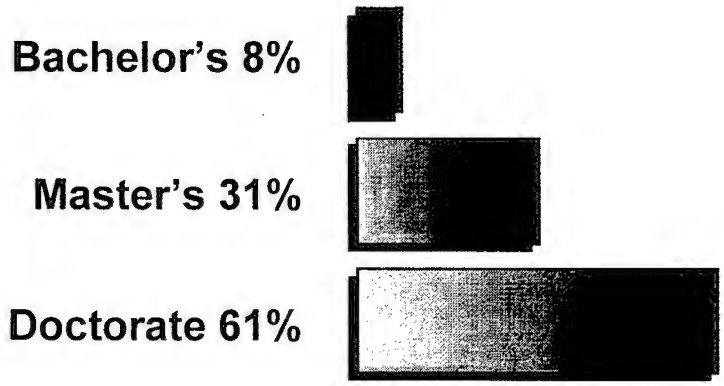
755 '97 769 '98 791 '99

# IDA's Employees

## Distribution of IDA Employees by Discipline



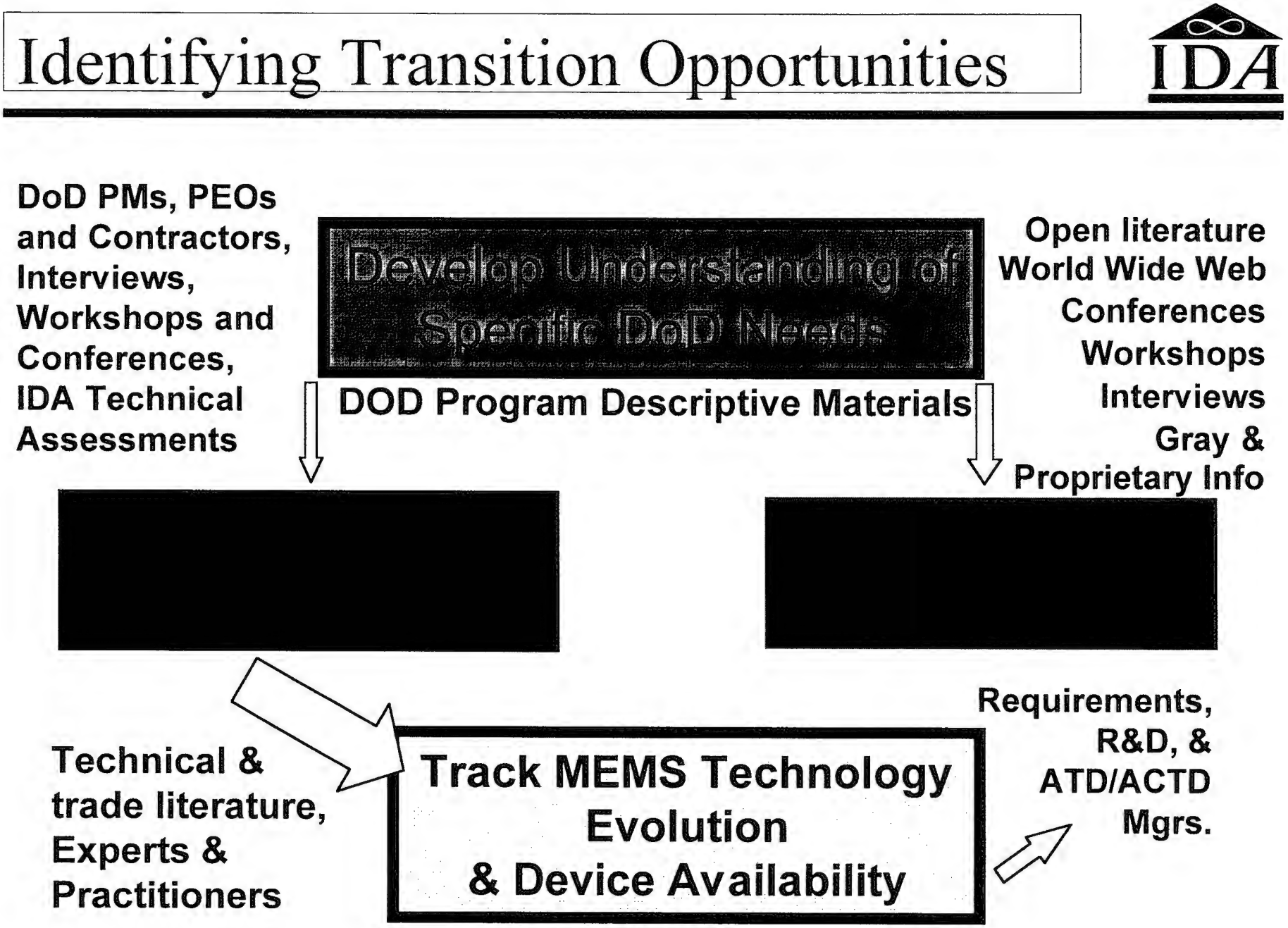

## Distribution of IDA Employees by Degree



# IDA MEMS Task Objectives

- Identify transition opportunities for MEMS in DoD
  - platforms
  - weapon systems
  - personnel
- Facilitate transition of MEMS
- Provide focus to research and development
  - prospective principal investigators
  - current principal investigators
  - contractors
- Apprise DARPA on Return on Investment
  - operations
  - logistics
  - science and technology

# Identifying Transition Opportunities



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# Barriers to Technology Transition

IDA

- Communication of Requirements, Needs, and Capabilities
- Biases Against "New" within the Acquisition Process
- Immaturity of MEMS Technology and the MEMS Industry

# Communications Issues

IDA

- Needs and Requirements not clearly communicated
  - DOD buys capabilities, not components, subcomponents, or devices
  - Translating Mission Element Needs Statements (MNS) and Operational Requirements Documents (ORDs) into system requirements is difficult; reducing system requirements to subsystems, components, and devices is even more challenging
- MEMS developers don't use the vocabulary of Program Managers and Prime Contractors
  - What does "it works" really mean?

# Acquisition Process Biases

IDA

- New Materiel Solutions to be undertaken only after all nonmateriel solutions have been exhausted
  - Doctrine
  - Training and operations
  - Modifications to existing hardware
- Existing commercial and/or government standards to be used in preference to new specifications or standards
- Strong preference for burden sharing
  - Fewer R&D resources favoring those who have infrastructure, clearances, existing relationships

# MEMS Industry Practices

IDA

- Immature Industry
  - Lack of Standards
    - Testing
    - Measurement
    - Reliability
  - Shortage of Capital
  - Enthusiasm for Devices
    - DoD buys solutions to problems

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# Lessons Learned (1)

IDA

- Communication of Requirements, Needs, and Desires
  - Solutions to problems, not devices, packages or specific products
- Customer Identification
  - DoD Program Managers advise Prime Contractors who have ultimate responsibility for system integration, performance, cost, and schedule
    - different audience
    - additional step in acquisition "marketing kill chain"
    - if prime likes device, sale is certain

# Lessons Learned (2)

IDA

- Resourcing RDT&E
  - Funding for basic and applied research is necessary but not sufficient
  - Funding for technology demonstrations, manufacturability, reliability, and integration into larger products is also necessary
- Systems Level exit criteria crucial to product level success
  - Satisfying the "ilities" of DoD make transition of new technology significantly more difficult than transition of "derivatives"

# Lessons Learned (3)

IDA

- Transitions are more likely
  - Consumers and researchers have achieved realistic understandings of problems, solution alternatives, and real-world trade-offs in cost and performance
  - Research and development documentation passes tests of "replicability"
  - Accepted test and evaluation processes, standards, and reporting permit realistic comparisons of multiple solutions to an operational problem

# Implications for Technology Transfers

IDA

- Importance of Effective Communication
  - Requirements, Needs, and Capabilities
- Importance of Focused Resource Investment
  - Demonstrations
  - Prototyping
- Importance of Broader Systems Focus
  - "It's the solution, not the product!"
- Importance of standards, specifications, and standard test methods to address commercial as well as government interest in reliability, maintainability, etc.

# Backup Charts

# Correlations of IDA's Efforts and Results


- Improved Communication
  - User needs, requirements translated into meaningful statements for producers
  - Producer capabilities translated into meaningful product/process descriptions for users
- Improved Understanding of Acquisition Process
  - Improved user requirements—statements of need
  - Technology demonstrations
  - Specifications, standards, and roadmapping
  - Earlier incorporation of MEMS technology development in Service/DOD Component funding cycles
- Maturing business practices

# Task Outcomes (1)

- Products included in Program Objective Memorandum for future systems
  - MEMS programmed into Joint Strike Fighter baseline configuration
  - MEMS included in DD21 future systems architecture
- Products included in POM for Preplanned Product Improvement
  - Wind-corrected Guided Munition Dispenser
- Products included in Advanced Technology Concept Demonstrations (ACTDs) or Advanced Technology Demonstrations (ATDs)
  - Micro-air Vehicle demonstrations
  - WINS demonstrations at 29 Palms
  - Polychrometer demonstration to Nonproliferation and Arms Control Technology Working Group

# Task Outcomes (2)

- Products covered by new industry/government standards
  - Inputs into IEEE 1451 family of "smart sensor" standards
  - Propulsion Instrumentation Working Group (PWIG) subcommittee on MEMS technology for gas turbine engine development instrumentation
- Product research, development, and doctrine development efforts incorporated as part of Military Service/DOD Component activities
  - Warrior Systems Technology Base Executive Steering Committee (TBESC)
  - Air Force Broad Area Announcement (BAA) for structures
  - Air Force BAA for munitions safing, arming, and fuzing devices
  - Navy BAA for munitions guidance, safing, arming, and fuzing devices

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DARPA asked IDA to identify barriers to the transition of MEMS technology from DARPA-funded laboratory-scale experiments to DOD military systems. Over the past 3 years, IDA has introduced MEMS technology to DOD systems managers, has translated DOD operational needs and requirements to MEMS Principal Investigators, has brokered MEMS technology demonstrations, and has advised DARPA on strategies and tactics to promote use of MEMS technology in DOD systems. This presentation attempts to identify technology transition lessons that may translate into more efficient and effective technology transfer.

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